Aquifer Storage Recovery Facilities for ASR Well 19 & Monitor Well 21 Startup and Cycle Testing Operations Manual

City of Victoria
Victoria, Texas

April 2018

Prepared for:

Prepared by:

CONTENTS

City of Victoria __ Aquifer Storage Recovery

Start-up and Cycle Testing Operations Manual – ASR Well 19

ASR Systems LLC

March 2018 (Draft)

INTRODUCTION

The Victoria Aquifer Storage and Recovery (ASR) Demonstration Project consists of: permitting, designing, and constructing an ASR retrofit to an existing City of Victoria groundwater production well (Well No. 19); constructing a 12-inch potable water pipeline for recharge and recovery purposes, and a 2-inch trickle flow pipeline for disinfection and lubrication purposes; conducting training and preparing this *Startup and Cycle Testing Operations Manual* (the “Manual”); cycle testing and assessment of the operational ASR well; and making presentations summarizing results. The Project Contractor is the Victoria County Groundwater Conservation District (the “Victoria County GCD”) and the primary Project Participant is the City of Victoria, Texas (the “City”). The Project consulting and engineering team consists of Arcadis U.S., Inc.; ASR Systems, LLC; and INTERA, Inc. (the “Arcadis Team”). The Project is partially funded by the Texas Water Development Board (TWDB) under Rider 25 to HB 1 (General Appropriations Act) of the 84th Legislature.

On April 28, 2017, the City received its authorization for a Class V Injection Well (Authorization No. 5X2500127) from the Texas Commission on Environmental Quality (TCEQ). That authorization includes permission to: operate Well 19 for recharge and recovery of water from the City’s water supply system; store up to 3,908 acre-feet of water at any one time; and conduct testing, data collection and analysis for up to two recharge and recovery Cycles.

The purpose of the Manual is to provide operations, start-up and cycle testing guidance to the City for Cycle 1. Preventive and repair maintenance direction is provided in separate documents delivered to the City by the respective equipment suppliers for this Project. This Manual is written to give the City specific information about the operation of facilities provided for this Project. Because this demonstration project includes the rehabilitation and retrofit of an existing well using a basic or manual operating approach, guidance related to electrically-operated valves, supervisory control and data acquisition (SCADA) systems, and/or programmable logic controllers (PLCs) is not provided.

The wellhead piping layout for ASR Well 19 is shown below in Exhibit 1. The system operates with a 12-inch pipeline connection to the City’s potable water distribution system. This connection conveys treated surface water from the distribution system into the ASR well during RECHARGE; and it conveys water pumped by the vertical turbine ASR recovery pump from the ASR well into the distribution system during RECOVERY. FLUSHING of water from the piping system or from the ASR well is routed to an adjacent surface ditch where it is recycled through the natural environmental system. A chemical feed system provides sodium hypochlorite (NaOCl) and ammonium sulfate [$(NH_4)_2SO_4$ or LAS] for restoration of the appropriate chloramine residual in the recovered water.

Prior to startup the well will have been disinfected and a two-hour pump test will have been conducted to confirm well and pump performance.

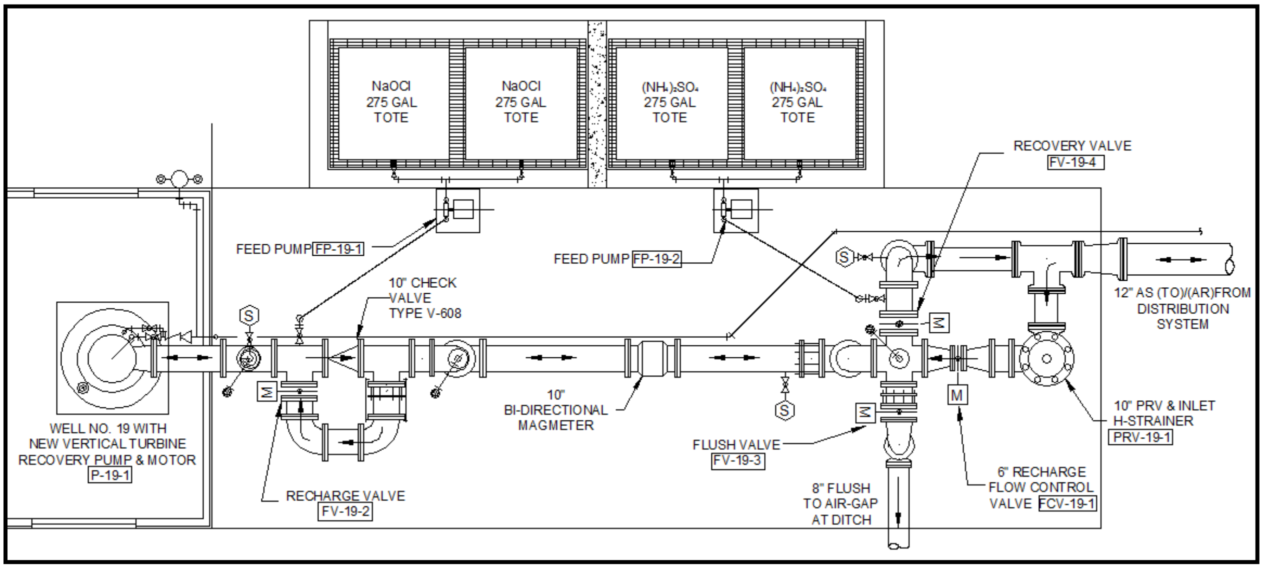

Exhibit 1 – ASR Wellhead Piping and Equipment

The various modes of operation of the ASR system are as follows:

- FLUSHING – Water pumped from the ASR Well and/or piping system to discharge
- RECHARGE – Water flows from the Distribution System to the ASR Well
- RECOVERY - Stored water is recovered from the ASR well, disinfection residual using chlorine and ammonia is restored, and the water is returned to the City's distribution system.

The system utilizes valves and pumps as shown in the table of Exhibit 2, with each items' status as shown for the various modes of operation. Operators should refer to this table in conjunction with the descriptions that follow.

Exhibit 2 – Equipment Status Summary

Tag No.	Item	Recharge	Storage/TF	Flush	Recovery
PRV-19-1	Pressure Reducing Valve	*Operating*	N/A	N/A	N/A
FCV-19-1	Recharge Flow Control Valve	*Manual Modulation*	Closed	Closed	Closed
FV-19-2	Column Recharge Valve	*Open**	Closed	Closed	Closed
FV-19-3	Flushing Valve	Closed	Closed	*Open*	Closed
FV-19-4	Recovery Valve	Closed	Closed	Closed	*Open*
P-19-1	ASR Pump	Off	Off	*On - AFD*	*On - AFD*
FP-19-1	NaOCl Pump	Off	Off	Off	On
FP-19-2	LAS Pump	Off	Off	Off	On

* Open only after purging air from wellhead piping by manual control of FCV-19-1.

The demonstration phase of the project will utilize manually operated valves. However; as indicated by the “M” symbol in Exhibit 1, the plan is that those valves may be fitted with motor operators and a PLC control system for automated operation in the future.

The first procedure in the start-up operational sequence is to confirm satisfactory operation of the wellhead facilities. This is achieved through implementation of the following steps.

SECTION 1

1. Manual Well Flush/Backflush: (See Exhibits 2 & 3)

Prior to introducing water from the distribution system to the ASR well, the piping flow path should be thoroughly flushed to ensure that no debris or bacteriological constituents are carried into the well. This is an essential exercise for system startup or after periods of non-use of the piping during Storage.

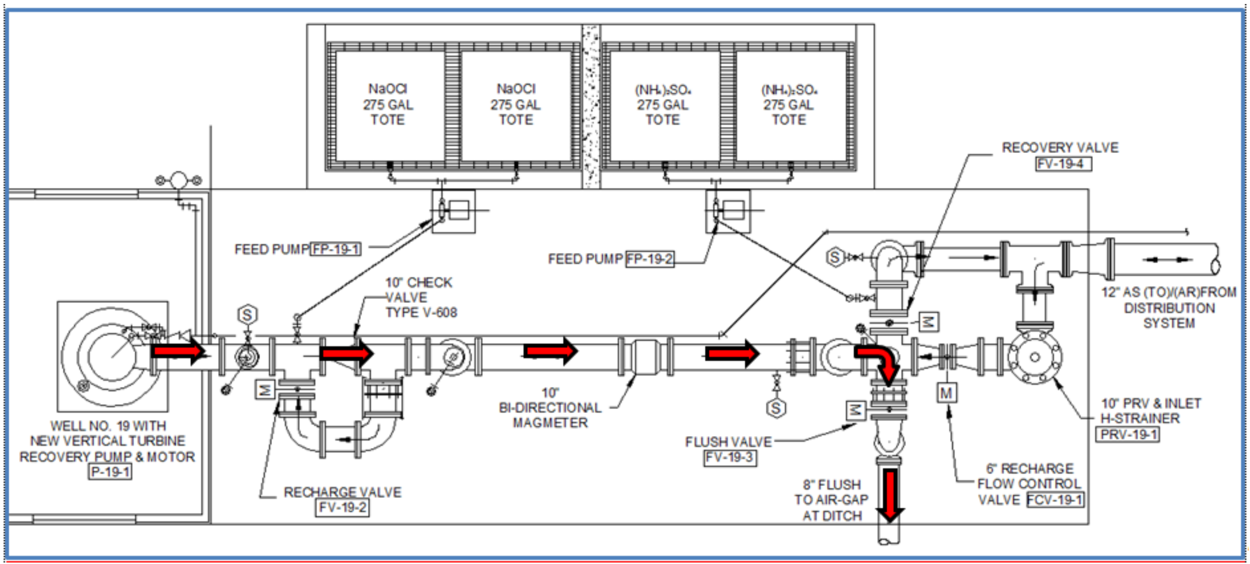

Exhibit 3 – Manual Well Flush/Backflush

- Record date, time, and depth to static water level at ASR Well 19, as measured by the transducer, the air line, and an electric tape. Electric tape measurements should be utilized to calibrate any differences between the three measurement methods. All depth to water level or pressure measurements should be referenced to the wellhead flange.
- Record the totalized value from the flowmeter prior to the Flushing mode of operation.
- Verify Close Position on Recharge Valve FCV-19-1 (Note: The valve will be manually operated to adjust the desired recharge flow. It is assumed that in the future if the well is automated it will be equipped with a motor operator and set up for automatic modulation to maintain a flow set point through a proportional–integral–derivative (PID) loop via a PLC control panel. The other valves as described below will also initially be set up for manual operation only. If the well is automated, motor operators will be installed to utilize the PLC control panel to automatically sequence the valves for each mode of operation).
- Verify Close Position for Pump Column Recharge Valve FV-19-2.
- Verify Close Position for Recovery Valve FC-19-4.
- Verify Open Position for Aquifer Flush Valve FV-19-3.
- Verify open path through 8” piping to Air Gap discharge at ditch.

- Verify well level transducer setting depth and check accuracy with electric tape.
- Verify and record Static Water Level (SWL) in Well Casing as reported through the existing PLC to the City's surface water treatment plant (SWTP). Turn off the manual trickle flow valve and verify the water level using the manual level gauge/bubbler. Then open trickle flow/ pre-lube valve.
- Start Recovery Pump P-19-1 adjustable frequency drive (AFD) to start flushing at low speed, about 60 percent of the design speed.
- Verify Flowmeter operation of the bi-directional magnetic Flow Meter and record totalized flow.
- Verify Pump Discharge Pressure gauge operation and record the discharge pressure.
- Observe and record pumped water quality.
- Observe Well Flush for 20 minutes, noting any change in turbidity or color.
- Manually adjust the speed of P-19-1 using the AFD, verify operation on the pump curve by reading flowrate and discharge pressure values.
- Pump Test: read well level, discharge pressure & flowrate, motor amps and motor voltage at 4 different speeds - Record Data.
- Throttle discharge valve as required to produce test head.
- After pumped water quality visually clears up, obtain baseline field water quality data from Discharge water (Temperature, DO, ORP, Conductivity, pH) using closed-cell sampling apparatus for DO and ORP.
- Stop Recovery Pump P-19-1.
- Record the final totalized value from the flowmeter display. The difference between the value and the initial value will be the quantity of water flushed from the well. That value should be added to the cumulative flush quantity.
- Manual Well Flush Terminated.

2. Manual Flush (Recharge Path) from Distribution System: (See Exhibits 2 & 4)

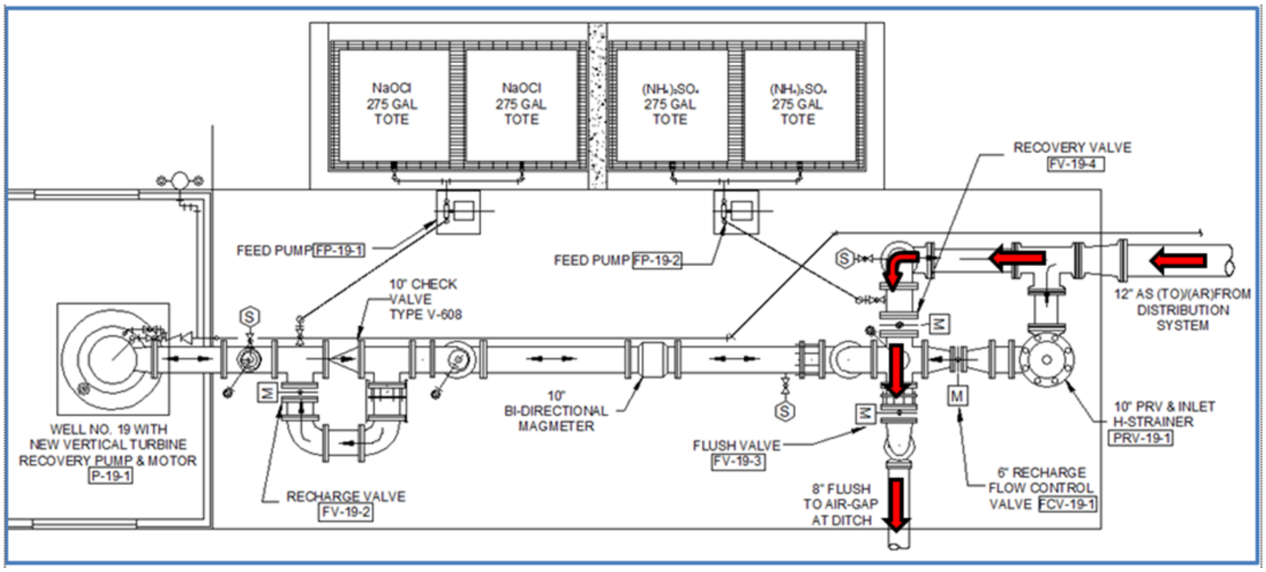

Exhibit 4 – Manual Flush Recharge Path from Distribution System

a. Verify Close Position of Recharge Valve FCV-19-1
b. Verify Close Position of Pump Column Recharge Valve FV-19-2
c. Verify Open Position for Aquifer Flush Valve FV-19-3
d. Verify open path to Air Gap
e. Verify and record system pressure upstream of PRV-19-1 via pressure gage on valve
f. Open Recharge Valve FV-19-4
g. Observe Flush for 10 minutes. Note any change in color or turbidity.
h. Close Recharge Valve FV-19-4
i. Manual Flush Terminated

3. Other Modes of Manual Operation:

After flushing the system's flow path for initial startup, or seasonal startup after a period of operating in the STORAGE mode, the other modes of operation can be initiated as required to meet the City's objectives. These modes include:

- RECHARGE
- STORAGE (with Trickle Flow of chloraminated water)
- WELL FLUSHING (as previously described)
- RECOVERY

RECHARGE MODE

For the Recharge mode of operation all valves and pumps are in the status as shown in the table of Exhibit 2. Recharge is the introduction of finished water into the well via the flow path as indicated in Exhibit 5.

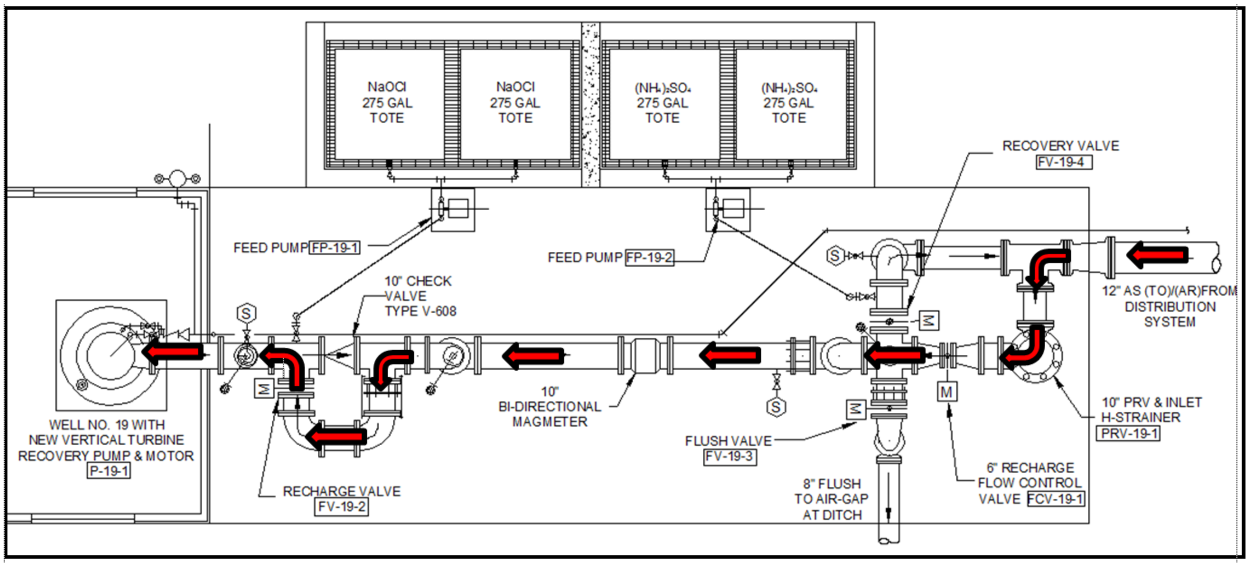

Exhibit 5 – Recharge of Water from Distribution System

Since the system utilizes manually operated valves, the operator will be required to manage the start of the recharge operation so as to vent air from the wellhead piping and pump column using the air and vacuum release valves (AVRVs) installed on the piping. This must be done carefully and slowly to avoid introduction of air into the aquifer storage zones of the well. The sequence shall be as follows:

- Refer to Exhibits 2 and 5 for the status of the valves and pumps for the system for the RECHARGE mode of operation.

- Record the totalized flow value as displayed on the flowmeter.

- Water from the City's distribution system shall enter the wellhead piping through PRV-19-1 which will automatically maintain the downstream pressure at the preset value [to be determined at startup, tentatively 20 pounds per square inch (psi)].

- The Column Recharge Valve FV-19-2 shall be in the Closed position.
- Slowly open the Recharge Flow Control Valve FCV-19-1 to approximately 50% open to allow water to enter the piping header and the air in the piping to automatically vent through the AVRVs.
- Listen for the venting of air from the AVRVs. When the venting stops, all the air should be purged from the section of piping up to FV-19-2.
- Slowly open the Column Recharge Valve to approximately 20% open and listen for the venting of air from the AVRV at the pump discharge. Listen for the rate of air venting and as the rate decreases slowly open FV-19-2 and manually modulate FCV-19-1 while monitoring the flowrate displayed on the Flowmeter until a rate of 250 gallons per minute (gpm) is reached. (This corresponds to a downhole velocity of approximately 1 foot per second (ft/sec) in the 10-inch pump column piping.)
- Maintain a flowrate of no more than 250 gpm until no more air vents from the AVRV and a positive pressure is achieved in the pump column piping at the wellhead. (After all the air is vented from the pump column piping the recharge rate can be increased without air entrainment in the flowstream that would carry air into the well.)
- Slowly adjust the flowrate through FCV-19-1 until the desired recharge flowrate is reached, tentatively in a range of 350 to 500 gpm, so long as wellhead pressure in the pump column does not (initially) exceed 20 psi.
- Monitor the flowrate for 5 minutes to ensure stable recharge operation.
- Continue the recharge operation in accordance with the City's recharge schedule. Monitor the recharge rate and adjust FCV-19-1 as required to maintain the desired recharge rate. (The City will need to develop a monitoring schedule based upon the hydraulic response of the well under recharge operations. Start with several visits per day and taper off to one visit per day once stable operation is achieved.)
- If the desired recharge rate can no longer be achieved by opening of FCV-19-1, then it may be necessary to terminate recharge and backflush the well to restore its recharge capacity.
- When ready to terminate recharge, first close FV-19-2, followed by closure of FCV-19-1.
- Record the totalized flow value from the flowmeter display. The difference between this value and the initial reading will be the volume of water stored during

the recharge operation. That value should be added to the cumulative recharge quantity.

- Initiate backflush as previously described. (The backflush operation is as shown in Exhibits 3 and 4 above.) The ideal backflush frequency and duration shall be determined by the operators based upon experience in operation of the ASR well. Start off with a backflush duration of 30 minutes and with the well pumping at its full capacity (AFD at 100%). Modify the duration, frequency and backflushing procedure as needed to ensure restoration of the recharge operations.

STORAGE MODE

For the Storage mode of operation all valves and pumps are in the status as shown in the table of Exhibit 2. All valves are closed and all pumps are off during the storage mode of operation. Storage is maintaining the volume of water added to the aquifer system through the ASR well for future use.

- During the storage period a Trickle Flow of chloraminated water from the 2" line from the distribution system is directed to the ASR well via the flow path as indicated in Exhibit 6. A suggested trickle flow rate is in the range of 2 gpm to 10 gpm.

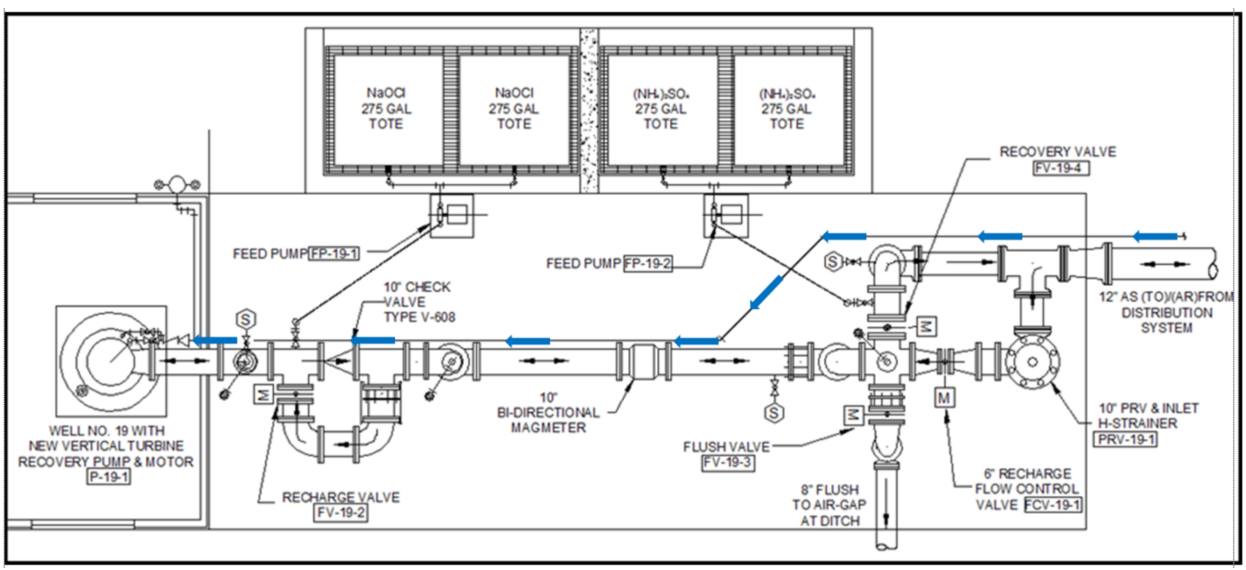

Exhibit 6 – Storage with Trickle Flow

- The Trickle Flow piping enters the well pump flange through a tube that routes the water down the well just above the bowl assembly.

- Additional Trickle Flow water is directed into the pre-lube connection on the pump head and serves the dual purpose of maintaining a flow of disinfected water in the pump column and providing pre-lube for the pump lineshaft bearings, keeping them wet at all times.

- The low flow Trickle Flow piping is manually valved. The valves can remain open at all times.

- The flow meter for the Trickle Flow/Pre-lube water shall be read periodically and the volume of water added since the last reading shall be added to the totalized Trickle Flow quantity.

RECOVERY MODE

For the Recovery mode of operation, the status of all valves and pumps is as shown in the table of Exhibit 2. Recovery consists of pumping the stored water from the well, reestablishing the disinfection residual in the recovered water, and returning the recovered water to the distribution system via the flow path, as indicated in Exhibit 7.

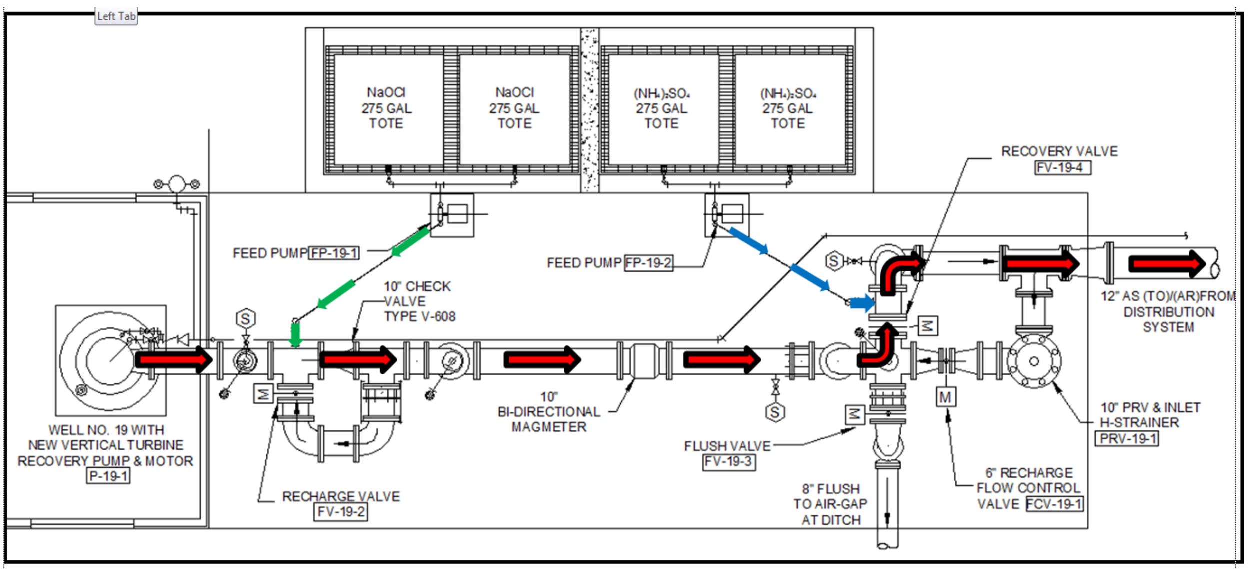

Exhibit 7 – Recovery to Distribution System

- Record the totalized value from the flowmeter display before starting the Recovery mode sequence.

- Recovery Valve FV-19-4 is opened to provide a path for recovered water to the distribution system.
- The chemical feed pumps: FP-19-1 for NaOCl and FP-19-2 for LAS shall be manually started and set at the feed rates set for proper dosing of the recovered water at the desired recovery rate from the ASR well. This will restore the required chloraminated residual to the recovered water.
- The ASR recovery pump P-19-1 shall be started and the pump speed shall be adjusted via the AFD to recover water at the desired rate.
- Upon termination of the Recovery mode of operation the recovery pump P-19-1 and the chemical feed pumps FP-19-1 and FP-19-2 shall be turned OFF.
- The check valve on the pump discharge will prevent reverse flow into the well. However, the Recovery Valve FV-19-4 shall be closed to ready the system for the next mode of operation.
- Record the totalized flow from the flowmeter. The difference between the initial value and the final value will be the recovered volume for this recharge event. That value should be added to the cumulative recovered quantity.
- Since this is a manually operated system, operators will need to visually monitor the levels of NaOCl and LAS in the chemical storage totes and operate the storage system to ensure a ready supply of chemicals as required for the Recovery operations.

SECTION 2

Interim Recharge:

During construction of wellhead facilities and equipping of the ASR well, recharge can be initiated as soon as a power supply is available for the magnetic flowmeter and the motor heater, and that pump shaft reverse rotation has been effectively prevented, such as with the specified non-reverse ratchet on the motor. This is called “interim recharge” and is often practiced at ASR wells during the time period between end of well construction and testing, and completion of construction for wellhead facilities. Quite often that period extends for eight to ten months, or longer, during which a substantial water volume can be recharged. For ASR sites with no pump in the well, interim recharge flow rates are usually limited since no backflushing can occur. For Victoria ASR Well 19, the well is already equipped with a pump, motor and flowmeter. The interim recharge time period will likely be short, as in a few days to weeks, since completion of construction of wellhead facilities is expected during March 2018.

Well Redevelopment:

Well 19's specific capacity was relatively low prior to the recently-completed well rehabilitation. It is hoped that the specific capacity will have improved, however the filter packing is conditioned for production, not for recharge. The filter pack needs to be redeveloped for both recharge and recovery (i.e.: both flow directions through the filter pack and surrounding formation). Upon completion of Steps 1 through 3 above in Section 1 (Manual Well Flush/Backflush; Manual Flush (Recharge Path) from Distribution System; Other Modes of Manual Operation), the following well redevelopment program should be implemented with the hope that this will increase specific capacity and associated recharge and recovery flow rates and volumes. The well conditioning process will take about one to two days, as follows, and will be implemented by the City of Victoria.

As discussed in detail below, the goal on the first day of well development is to conduct three backwash cycles of 30 minutes each [a triple backwash ("3x BW")], followed by a high rate injection slug for 30 minutes, followed by a second 3x BW, followed by a second, high rate injection slug. On the second day, conduct a 3X BW followed by a 30-minute high rate injection slug, followed by a 3X BW. Cycle 1 recharge would then begin or resume, assuming that turbidity in the pumped water has reduced to acceptable levels and that recharge flow rates and specific capacity have reached a plateau. This well conditioning procedure has typically been quite effective at improving well hydraulic performance. If a plateau has not been reached, another series would be implemented. For each step, hydraulic data is recorded after exactly 25 minutes, enabling comparison with data from many other well conditioning and redevelopment projects nationwide that have utilized these procedures.

a. Wait until water level recovers to the previously-measured static water level following Steps 1 through 3, as described above in Section 1. This could be overnight or perhaps a shorter duration such as one hour. Record new static water level.

b. Pump well to Discharge for 30 minutes at 1,500 gpm (AFD at 100%), noting recovered water turbidity at five-minute intervals. Record water level and rate at 25 minutes. Note time and volume recovered.

c. Turn off pump and wait a few minutes for partial (but not full) recovery to static water level. Note time and water level at end.

d. Repeat b. and c. two more times to constitute a triple backwash (aka "3x BW"). There would be no recharge between the backwash cycles.

e. Recharge at wellhead pressure of 40 psi in the well casing for 30 minutes. Anticipated flow rate is about 500 gpm. Record water level (or casing pressure), and flow rate at 25 minutes. Note time and volume recharged.

f. Following a 10-minute delay after recharge stop, repeat steps b. through e. again.

g. Rest well overnight to relax formation.

h. Repeat steps b. through f. one more time.

i. If there is steady improvement in recharge flow rates with successive well development cycles, and declining turbidity in the pumped water, continue with additional cycles until recharge flow rates appear to have reached a plateau. If there has been no further improvement after the first three cycles, terminate the well redevelopment program.

j. In preparation of the Recharge cycle start, rest well for 30 minutes, and then conduct steps c. through e. with 15-minute delays between pump stop and pump restart.

k. Rest well 30 minutes, and then start long term Recharge cycle (Cycle 1 described below). Record water level (or casing pressure) and Recharge rate at 25 and 60 minutes after start.

SECTION 3

CYCLE 1 Testing Program

Background

An initial objective for this cycle testing program is to determine a combination of recharge flow rate, recharge pressure, backflushing frequency, and backflushing procedures that achieves a reasonably stable recharge flow rate over a period of several months while not causing wellhead pressure in the casing annulus to rise above a target pressure, to be established. External factors such as seasonal variability in local static water levels, and well clogging and unclogging will tend to cause the actual flow rate to vary around a longer-term average recharge flow rate. It is anticipated that this balancing process may require a few weeks to work out. The 20-psi initial target wellhead pressure in the pump column will later be adjusted upward, after the head loss through the pump column has been determined. Available drawdown in the well, whether through backflushing or long-term pumping, should always exceed the increase in water levels occurring during recharge, preferably by a wide margin. This margin is needed to ensure that any subsequent well clogging by particulates can be unclogged.

Wellhead facilities for this cycle test are manually operated. There is no SCADA or instrumentation and control (I&C) system to record flows, levels, pressures, volumes, water quality, etc. Operations will initially need to be monitored daily, and probably adjusted weekly, until well and aquifer hydraulic response to aquifer recharge are better understood. Recharge monitoring frequency may then be reduced. All data should be recorded in Excel format and provided to the ARCADIS Team and other interested parties on a weekly basis. A suggested data collection template is included in Appendix B.

After a recharge period of a few months, half of the cumulative recharge volume will be recovered. The schedule for the beginning of recovery will be determined so that the end of recovery will be consistent with completion of the TWDB-funded demonstration project on schedule. However, the City may continue to conduct cycle testing after the demonstration project draft report has been prepared.

Recovery flow rate is expected to be 1,500 gpm. Recharge flow rate is as yet unknown, but probably less than the previously-assumed 800 gpm, reflecting a depth to static water level of about 20 to 30 feet compared to the historic static water level of about 80 to 90 feet below land surface. With a higher static water level, there will be less available head to drive the recharge process.

Recharge is expected to begin during late March or early April 2018 following completion of construction of wellhead facilities. During early August 2018 recharge will be interrupted for a one-week storage period, following which the well will be pumped to Discharge at a flow rate and duration that achieves a representative sample of the recovered water quality that would be recovered to the distribution system several months later at the end of Cycle 1. A sample will be collected for lab analysis at the end of the recovery pumping period. The sample will be analyzed for all the constituents listed in Table 1, List C. Lab results will be available after about one month, providing the City and TCEQ with the confidence that water to be recovered at the end of Cycle 1 can be disinfected and then pumped to the water distribution system, meeting all SDWA drinking water standards. After the lab sample has been collected, recharge into ASR Well 19 would resume.

Well clogging is not unusual in an ASR well. This may be due to physical clogging with particulates or air; microbial clogging due to bacterial activity; or geochemical clogging due to potential subsurface reactions. Microbial clogging is not expected since the well will have recently been disinfected, and recharge will be with water that has a chlorine residual. Geochemical clogging is also not expected; however, it may occur due to potential reactions between the recharge water, the native groundwater, and the minerals in the aquifer. In order to meet the TWDB funding schedule, no coring, core lab analysis, or geochemical investigations were conducted at this location. Physical clogging is anticipated, such as may be due to entrained air, or any particulates in the recharge water that may be from solids present in the distribution system such as sand, mobilized by changes in flow velocity and/or direction when ASR recharge begins. Clogging may also be due to rust and calcium carbonate deposits within the well casing and screen.

Periodic backflushing and well redevelopment can purge these particulates from the well, restoring recharge capacity. Backflushing frequency is currently unknown but is most likely in a range of twice a week to once every two weeks. A reasonable starting point would be once per week. Backflushing procedure remains to be determined, however a reasonable starting point would be to pump the well at its maximum design rate of 1,500 gpm for 25 minutes; rest the well for five minutes; then repeat that sequence one or two more times. Based upon operating experience, adjust the backflushing duration, frequency and number of backflushing periods. A reasonable goal would be to establish the viability of a single backflush for 25 minutes, however that remains to be verified through experience.

Recharge and Recovery Flow Rates

With well rehabilitation and redevelopment, injection specific capacity may improve. Furthermore, wellhead modifications now underway will enable recharge under pressure at the wellhead, eliminating any overflow from the previously-unsealed wellhead. For planning purposes, an average recharge flow rate of 350 gpm to 500 gpm is anticipated. Total time remaining for cycle testing while complying with TWDB schedule constraints is currently estimated at up to about eight months. It is assumed that recharge would continue for about six months, followed by a storage period of two weeks, followed by a recovery period of about one month. These are tentative estimates, to be refined following beginning of cycle testing. Half of the stored water volume would be recovered, leaving the remainder as a contribution to the Target Storage Volume (TSV) for this well after it is put into full-scale ASR operation. Once the TSV has been established and achieved, essentially all subsequently stored water should be recoverable when needed. The planned cycle test may show that the Buffer Zone volume needed for this well is less than 50% of the TSV, reflecting the fresh water quality of the Evangeline aquifer in this area. Whatever is ultimately determined to be the TSV and the Buffer Zone volume for this well, the cumulative recovered water volume would typically approach but not exceed the recharge water volume.

Bypass Filter at Wellhead

It is not uncommon at ASR wells for occasional slugs of poor quality water to arrive at the wellhead and then be recharged, contributing to well clogging. This is often associated with flow reversals in the distribution system, such as may occur during a major fire or pipeline break, or initiation of ASR recharge. For older distribution systems with cast iron or ductile iron pipes, recharge of rusty water may be more common. We understand that piping conveying water from the City of Victoria Surface Water Treatment Plant (SWTP) to ASR Well 19 is relatively new and of PVC construction. Consequently, the risk of particulate well clogging is greatly reduced. We suggest that the City may wish to consider installing a bypass filter in the ASR recharge piping at future ASR wells, observation of which would then be correlated with well clogging experience. This would be a 5-micron cartridge filter in a see-through glass enclosure, as shown in Figure 1. For the four example bypass filters shown in this figure, all four started out white. Two of the four subsequently turned dark brown within a few days. Flow rate through the filter would be in the range of 2 to 3 gpm, continuous. This filter would be changed initially weekly during the cycle testing recharge period. Used filters would be tagged to record the associated dates, and then stored at the associated wellhouse until at least the end of the cycle testing period. This has proven to be a valuable operating tool at other ASR wells. A bypass filter may also be installed on the "recovery to discharge" piping so that well clogging can be more easily characterized as to whether it is due to particulates, microbial or geochemical reactions, or some combination.

Monitor Well 21

This monitor well is approximately 2,100 feet east of ASR Well 19. It is a production well that supplies water to the SWTP when needed during a drought, flood, or other emergency. It is used infrequently. Depth to water level will be measured in this well prior to recharge; prior to collection of lab samples from Well 19, and at beginning and end of recovery from Well 19. Samples will be pumped from Well 21 at the beginning, middle and end of recharge. Any change in water quality would indicate whether the water recharged at Well 19 has reached Well 21. Samples from Well 21 will be analyzed for the constituents listed in Table 1, List D. The City will collect the samples and deliver them to the lab. All water quality data will be provided to the Arcadis Team in a suggested standard format, such as that shown in Appendix B.

Regional Water Level Monitoring

Historic water levels in the Victoria area have consistently indicated the existence of a “bowl” in the potentiometric surface, which maps water levels relative to mean sea level in wells in the Evangeline aquifer. This was caused by the City’s production wells and by surrounding agricultural groundwater production. In 2001 the City changed from a groundwater supply to a surface water supply, eliminating almost all the municipal groundwater production. There may also have been a reduction in agricultural pumping since then. Historic groundwater static water level at Well 19 was about 80 to 90 feet below ground surface. A recent (2017) measurement showed it to be 30 feet below the wellhead flange while in January 2018 it was at 22 feet below the flange. The “bowl” has been greatly reduced or possibly eliminated due to rising groundwater levels.

Control of the water stored in ASR wells operating within a “bowl” is relatively easy since the water will not move very far from the ASR wells. However, if the “bowl” is gone from the area around Victoria, then it becomes important to ascertain the local gradient in the potentiometric surface, the predominant direction of groundwater movement; the bulk porosity of the sands in the storage interval of the Evangeline aquifer, and the hydraulic conductivity of the sands. From this information, the lateral rate and direction of groundwater movement can be calculated. Typical velocities of groundwater movement in Texas to date have been slow, on the order of a few feet per year. For most ASR wellfield operations, this would be insignificant since the stored water “bubble” typically extends radially several hundred to about a thousand feet.

The City has recently begun collecting water level data at a few other wells in its service area. A regular water level measurement program at selected wells over a period of a year or more would be invaluable at such time in the future as the City may elect to seek an operating permit from TCEQ for ASR Well 19 or possible future additional ASR wells. Ideally the wells selected for periodic measurement of water levels would be screened in the Evangeline aquifer and would be distributed within the City and surrounding area so that a potentiometric surface map could be drawn for this area.

Baseline Water Quality

Samples were obtained during January 2017 for lab analysis of primary and secondary drinking water standard constituents. Samples were obtained for Wells 19, 21 and (during 2016) for the finished water from the SWTP. Results are shown in Appendix A. Results are unremarkable, other than indicating that chloride should be a reasonable and relatively inexpensive natural tracer for determining whether recharge water from ASR Well 19 has reached Monitor Well 21. A declining trend of monthly chloride concentrations at Well 21 would suggest that recharge water from ASR Well 19 has reached Monitor Well 21. The distance between the two wells is approximately 2,100 feet. Recently-collected chloride concentrations are as follows:

	Chloride Concentration (mg/l)
Treated Drinking Water	49
ASR Well 19	108
Monitor Well 21	92

Supplemental data will also be obtained for conductivity at Well 21, at the time of sample collection for chloride analysis. Conductivity measurements are inexpensive but also more variable than chloride measurements since they are affected by variability in pH and temperature.

Cycle Testing Operations Plan

Day One

1. Measure and record depth to static water level at Wells 19 and 21. At Wells 19 and 21 record baseline conductivity and obtain samples for baseline chloride analysis.

It is possible that this data for Well 19 may already have been obtained during the previously-conducted two-hour pumping test to confirm satisfactory performance of the pump. Also at Well 21, record flowmeter reading.

2. Record cumulative volume on flowmeter totalizer at ASR Well 19, and associated date and time when recharge begins at Well 19. Consider re-setting flowmeter totalizer to zero immediately prior to startup.
3. Start recharge, as described in Section 3. Adjust recharge flow rate upward in stages so that wellhead pressure in the pump column, as measured at the wellhead flange, is 20 psi. Use the pressure reducing valve (PRV) at the wellhead on the recharge piping to adjust the pressure and associated flow rate.
4. Record water level rise in the casing annulus after 25 minutes, as measured by the transducer. Continue recharge for a total of about one hour. Record wellhead pressure at the pressure gage on the wellhead flange after the casing annulus water level rises above the wellhead flange. Record flow rate after one hour; wellhead pressure in the pump column after one hour, and wellhead pressure in the casing annulus after one hour. There should be a difference between the two pressures, reflecting head loss with flow down the pump column.
5. If necessary after one hour, adjust the PRV so that wellhead pressure in the pump column is 20 psi.

Day Two

6. Record flow rate, wellhead pressure on pump column; wellhead pressure in casing annulus, cumulative volume, date, time.
7. Obtain recharge water quality samples for field constituents (Temperature, DO, ORP, Conductivity, pH, Cl_2) using closed- cell sampling apparatus for DO and ORP. Collect recharge water quality samples for lab analysis of constituents listed in Table 1, List A, to be collected monthly during the recharge period, and at the end of recharge. Field and lab samples to be collected from ASR Well 19 (and Production/Monitor Well 21 if not obtained on Day 1). If necessary, re-schedule sampling so that it occurs on days when the lab is receiving samples, ie: not Friday, Saturday or Sunday.
8. Adjust wellhead pressure on pump column upward incrementally with the goal of achieving a wellhead pressure in the casing annulus approaching a maximum of 30 psi. Do this in small, daily increments of about 5 psi, over a period of a few days.

Days Three through Seven

9. Repeat Day Two, but without Step 7. Recharge water quality sampling at Well 19 should be collected monthly after the initial sample, immediately prior to a backflush event. Suggested sampling dates will be established after recharge begins. Samples at Well 21 would also be collected monthly during the recharge period.
10. Backflush the well after one week of recharge, using the following initial procedure:

    a). Before stopping recharge, record flow rate, wellhead pressure on pump column, wellhead pressure in casing annulus, cumulative volume, date, time.

    b) Stop recharge and wait 15 minutes for partial water level recovery.

    c) Set AFD at 100% and start pump.

    d) Note turbidity and color of produced water every five minutes for 25 minutes, collecting samples in five glass jars.

    e) Record pumping water level and flow rate, then turn off the pump after 25 minutes.

    f) When convenient, obtain photograph of glass jars arranged in sequential time, with a white background (such as foam core board).

    g) After ten minutes, start pump and repeat steps d) through f).

    h) Repeat step g). This will be the third and final backflush in a series of three.

    i) Record the cumulative volume discharged during backflushing.

    j) Purge H-strainer for a few seconds and note any particulates on the strainer or turbidity in the purged water.

    k) After 15 minutes rest for water level recovery, resume recharge as per Day One, Step 1.
11. Email weekly summary to Consultant Team, along with water quality data as it becomes available, and photos of the “turbidity jars” and bypass filters (if installed). Operational adjustments, if appropriate, will then be recommended to the City.

Subsequent Weeks During Recharge Period

12. Make whatever adjustments to flows, pressures, backflush procedure and backflush frequency are recommended by the Arcadis Team following weekly reviews of the data.
13. Obtain lab samples monthly from Wells 19 and 21 during recharge, plus field water quality data at the time of each lab sample collection. The last recharge water samples would be collected just prior to the end of recharge. At Well 21, measure static water levels just prior to pumping the well to obtain samples.

August 2018 (Subject to Adjustment As Cycle Testing Proceeds)

14. After approximately four months of recharge into ASR Well 19, stop recharge for one week during what will probably be a peak water demand period for the City. Then recover water to Discharge for a duration and flow rate that achieves a water quality considered by the City to be representative of what would be recovered to the distribution system at the end of Cycle 1. Collect a sample at the end of recovery for a complete analysis for constituents listed in Table 1, List C, including lab and field analyses. Lab results will be available within about a month and would provide confidence to the City and TCEQ that water to be recovered at the end of Cycle 1 could be recovered to the distribution system instead of to discharge, meeting all drinking water standards.
15. Resume recharge into ASR Well 19 for an additional period of approximately two to three months.

End of Recharge/ Beginning of Recovery

16. Prepare ASR Well 19 disinfection facilities for continuous operation.
17. Upon completion of recharge, collect a final recharge water sample as in 7. above, then stop recharge. Wait two weeks. Measure static water level, then conduct a 3x backwash cycle, collecting data on flow rate and water level during each backwash after 25 minutes. Begin recovery at the full capacity of the pump, about 1,500 gpm. Record flow rate, water level and cumulative volume after 25 minutes of recovery. Recover <u>half</u> of the cumulative volume stored to date, probably over a period of several days. Obtain water quality samples for field and lab analysis one hour after the beginning, and at the middle and end of recovery. At the time of each recovery sampling event, record flow rate, discharge pressure and pumping water level, and cumulative volume recovered. One day after the end of recovery, record static water level.

Cycle Testing Report

Quarterly reports will be provided by the City to TCEQ as per one of the conditions in the TCEQ Letter of Authorization dated April 28, 2017 (Appendix C).

Upon completion of cycle testing, and receipt of all hydraulic and water quality data, a draft report will be prepared, analyzing the data, drawing conclusions, and making recommendations. This report will be reviewed by the Arcadis Team, then by the City and Victoria County GCD, and will then be sent to TWDB for review. A final report will then be prepared. A copy of that report for Cycle 1 will also be provided to TCEQ after it has been accepted by the TWDB.

The City's authorization also requires that TCEQ be provided with a well completion report describing the conversion work performed on Well 19. It is likely that the report to the TWDB will fulfill this TCEQ requirement.

FIGURE 1 BYPASS FILTER EXAMPLES

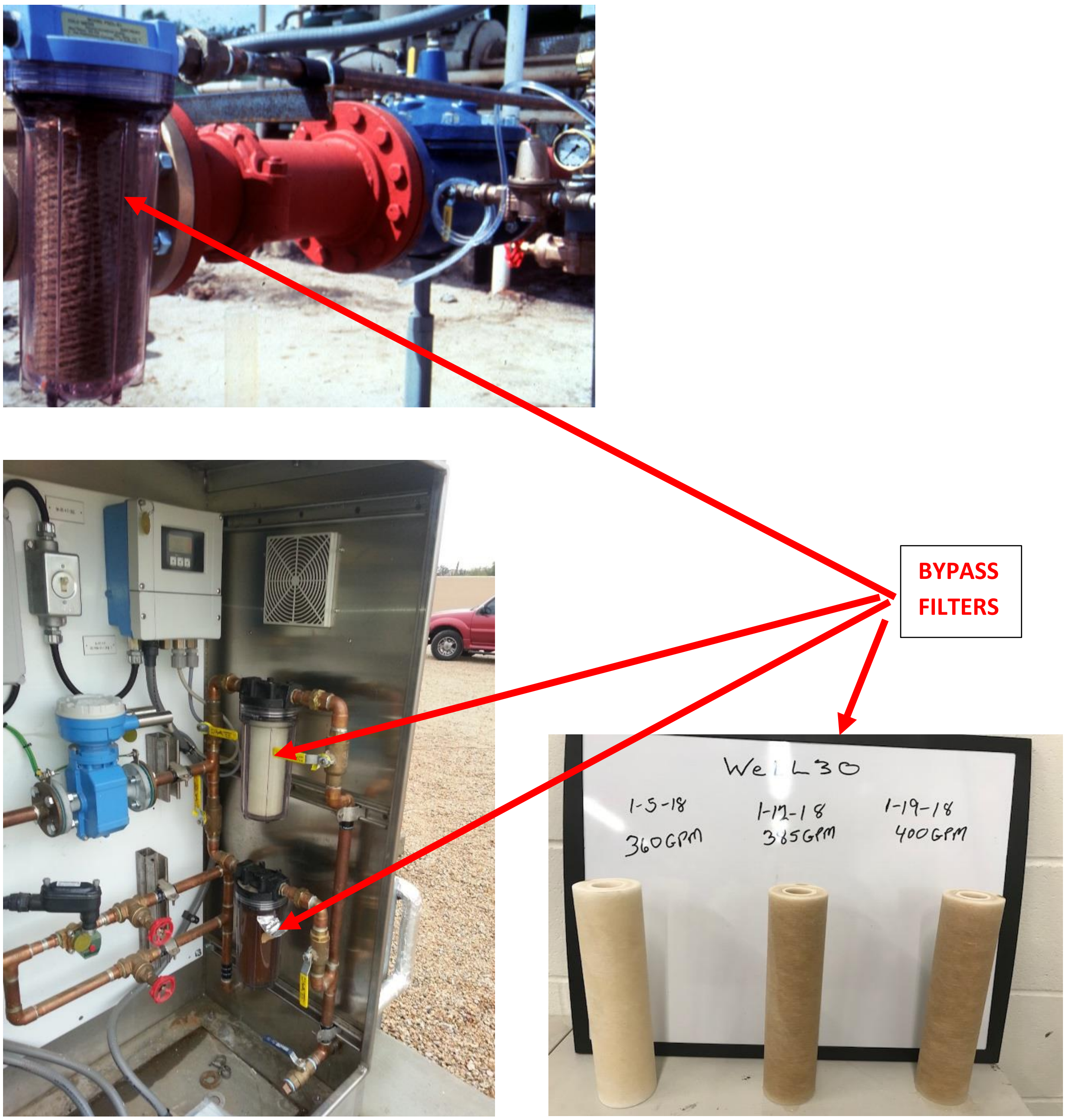

Table 1

City of Victoria ASR Cycle Testing Program – Water Quality Monitoring Plan

ASR Well 19 and Production/ Monitor Well 21

List A Constituents

To be obtained for ASR Well 19 at the beginning and end during recharge, and monthly in between. (Total about 6 samples):

PDWS	SDWS	Other Lab Constituents	Field Constituents
Fluoride	Chloride	Aluminum	Dissolved Oxygen
Turbidity	Sulfate	Ammonia	Oxidation Reduction Potential
	TDS	Total Alkalinity	Temperature
		Total Suspended Solids	pH
		Calcium	Conductivity
		Magnesium	Chlorine Residual
		Sodium	
		Potassium	
		Total Silica	
		Total Hardness	
		Total Phosphate	
		Total Organic Carbon	
		Total Trihalomethanes	
		Total Haloacetic Acids	
		Bromate	

List B Constituents

To be obtained for ASR Well 19 one hour after the beginning of recovery, and at the middle and end of recovery. (Total 3 samples)

All of List A constituents plus the following:

Arsenic (filtered)

Arsenic (unfiltered)

Iron (dissolved)

Iron (total)

Manganese (dissolved)

Manganese (total)

Lead

List C Constituents

To be obtained from a pumped sample at ASR Well 19 at the end of Cycle 1 recovery. (Total 1 sample)

All of the constituents listed in Table 1, which were the baseline water quality analyses for Wells 19, 21 and for the Finished Water from the Surface Water Treatment Plant.

List D Constituents

To be obtained from a pumped sample at Production/ Monitor Well 21 at the beginning and end of recharge into ASR Well 19, and monthly in between.

Chloride

Conductivity

APPENDIX A

SWTP 2016 Finished Water Analysis

Laboratory Measurements	Units	Result
Alkalinity, Total	mg/L	**166.0**
Ammonia	mg/L	**0.01**
Bicarbonate	mg/L	**224.0**
Chloride	mg/L	**49.0**
Fluoride	mg/L	**0.62**
Hardness, Total	mg/L	**192.0**
ORP	mV	**442.0**
Phosphate, Total	mg/L	**1.08**
Phosphorus	mg/L	**0.38**
Silica	mg/L	**19.0**
Sulfate	mg/L	**22.0**
Sulfide	mg/L	**0.020**
Total Dissolved Solids	mg/L	**325.0**
Total Organic Carbon	mg/L	**1.5**
Total Trihalomethanes		
dichlorobromomethane	µg/L	**22.0**
bromoform	µg/L	**1.80**
dibromochloromethane	µg/L	**15.0**
chloroform	µg/L	**18.0**
Bromate	µg/L	**<0.002**

Well 19 2017 Raw Water Analysis

Laboratory Measurements	Units	Result
Alkalinity, Total	mg/L	**260.0**
Ammonia	mg/L	**0.22**
Bicarbonate	mg/L	**205.0**
Chloride	mg/L	**108.0**
Fluoride	mg/L	**0.53**
Hardness, Total	mg/L	**88.0**
ORP	mV	**131.0**
Phosphate, Total	mg/L	**0.07**
Phosphorus	mg/L	**1.7**
Silica	mg/L	**30.0**
Sulfate	mg/L	**19.1**
Sulfide	mg/L	**0.02**
Total Dissolved Solids	mg/L	**504.0**
Total Organic Carbon	mg/L	**<1.00**
Total Trihalomethanes		
dichlorobromomethane	µg/L	**0.50**
bromoform	µg/L	**0.50**
dibromochloromethane	µg/L	**0.50**
chloroform	µg/L	**0.50**
Bromate	µg/L	**<0.002**

Well 21 2017 Raw Water Analysis

Laboratory Measurements	Units	Result
Alkalinity, Total	mg/L	**271.0**
Ammonia	mg/L	**<0.10**
Bicarbonate	mg/L	**359.0**
Chloride	mg/L	**92.0**
Fluoride	mg/L	**0.54**
Hardness, Total	mg/L	**135.0**
ORP	mV	**201.0**
Phosphate, Total	mg/L	**0.03**
Phosphorus	mg/L	**0.2**
Silica	mg/L	**27.0**
Sulfate	mg/L	**<2.00**
Sulfide	mg/L	**<0.01**
Total Dissolved Solids	mg/L	**455.0**
Total Organic Carbon	mg/L	**<1.00**
Total Trihalomethanes		
dichlorobromomethane	µg/L	**0.50**
bromoform	µg/L	**0.50**
dibromochloromethane	µg/L	**0.50**
chloroform	µg/L	**0.50**
Bromate	µg/L	**<0.002**

Bromide	µg/L	**<0.12**	Bromide	µg/L	**0.34**	Bromide	µg/L	**<0.20**
Turbidity	NTU	**0.03**	Turbidity	NTU	**0.29**	Turbidity	NTU	**1.70**
Color	PCU	**0.0**	Color	PCU	**2.0**	Color	PCU	**2.0**
Total Suspended Solids	mg/L	**0.0572**	Total Suspended Solids	mg/L	**0.1332**	Total Suspended Solids	mg/L	**1.1655**
Carbonate Alkalinity	mg/L	**<2.0**	Carbonate Alkalinity	mg/L	**0.0**	Carbonate Alkalinity	mg/L	**<20.0**
Non-carbonate Hardness	mg/L	**26.0**	Non-carbonate Hardness	mg/L	**0.0**	Non-carbonate Hardness	mg/L	**0.0**
Orthophosphate	mg/L	**0.67**	Orthophosphate	mg/L	**<0.1**	Orthophosphate	mg/L	**<1.0**
Hydrogen Sulfide	mg/L	**0.000**	Hydrogen Sulfide	mg/L	**0.022**	Hydrogen Sulfide	mg/L	**0.023**
Dissolved Oxygen	mg/L	**9.1**	Dissolved Oxygen	mg/L	**3.1**	Dissolved Oxygen	mg/L	**1.3**
Metals			***Metals***			***Metals***		
Antimony	mg/L	**<0.0010**	Antimony	mg/L	**<0.0018**	Antimony	mg/L	**<0.0018**
Arsenic	mg/L	**0.0021**	Arsenic	mg/L	**<0.0029**	Arsenic	mg/L	**0.0156**
Arsenic, Dissolved	mg/L	**<2.00**	Arsenic, Dissolved	mg/L	**<0.005**	Arsenic, Dissolved	mg/L	**0.0072**
Barium	mg/L	**0.341**	Barium	mg/L	**0.190**	Barium	mg/L	**1.59**
Beryllium	mg/L	**<0.00080**	Beryllium	mg/L	**<0.0005**	Beryllium	mg/L	**<0.0005**
Cadmium	mg/L	**<0.0010**	Cadmium	mg/L	**<0.0005**	Cadmium	mg/L	**<0.0005**
Calcium	mg/L	**48.0**	Calcium	mg/L	**22.3**	Calcium	mg/L	**35.2**
Chromium	mg/L	**<0.0100**	Chromium	mg/L	**0.0006**	Chromium	mg/L	**0.0009**
Copper	mg/L	**0.0265**	Copper	mg/L	**0.0041**	Copper	mg/L	**0.0892**
Iron	mg/L	**<0.010**	Iron	mg/L	**0.198**	Iron	mg/L	**0.697**
Iron, Dissolved	mg/L	**<20.00**	Iron, Dissolved	mg/L	**<0.005**	Iron, Dissolved	mg/L	**0.0143**
Lead	mg/L	**<0.0010**	Lead	mg/L	**<0.0009**	Lead	mg/L	**0.0068**
Magnesium	mg/L	**9.62**	Magnesium	mg/L	**7.48**	Magnesium	mg/L	**9.54**
Manganese	mg/L	**<0.0010**	Manganese	mg/L	**0.0076**	Manganese	mg/L	**0.0961**
Manganese, Dissolved	mg/L	**<0.005**	Manganese, Dissolved	mg/L	**0.0068**	Manganese, Dissolved	mg/L	**0.0888**
Mercury	mg/L	**<0.00040**	Mercury	mg/L	**<0.0002**	Mercury	mg/L	**<0.20**
Nickel	mg/L	**0.002**	Nickel	mg/L	**<0.0005**	Nickel	mg/L	**<0.0005**
Potassium	mg/L	**3.45**	Potassium	mg/L	**2.6**	Potassium	mg/L	**2.1**

Selenium	mg/L	**<0.0030**	Selenium	mg/L	**<0.0038**	Selenium	mg/L	**<0.0038**
Silver	mg/L	**<0.0100**	Silver	mg/L	**<0.0005**	Silver	mg/L	**<0.0005**
Sodium	mg/L	**50.8**	Sodium	mg/L	**226.0**	Sodium	mg/L	**130.0**
Thallium	mg/L	**<0.00040**	Thallium	mg/L	**<0.002**	Thallium	mg/L	**<0.002**
Zinc	mg/L	**<0.0050**	Zinc	mg/L	**<0.0032**	Zinc	mg/L	**0.0345**
Inorganic Chemicals			***Inorganic Chemicals***			***Inorganic Chemicals***		
Cyanide	mg/L	**0.03**	Cyanide	mg/L	**<0.005**	Cyanide	mg/L	**<0.005**
Nitrate	mg/L	**0.43**	Nitrate	mg/L	**0.30**	Nitrate	mg/L	**0.43**
Nitrite	mg/L	**<0.01**	Nitrite	mg/L	**<0.05**	Nitrite	mg/L	**<0.05**
Acidity	mg/L	**<20.0**	Acidity	mg/L	**<20.0**	Acidity	mg/L	**<20.0**
pH	SU	**7.5**	pH	SU	**7.86**	pH	SU	**7.36**
Synthetic Organic Chemicals			***Synthetic Organic Chemicals***			***Synthetic Organic Chemicals***		
Endrin	µg/L	**<0.01**	Endrin	µg/L	**<0.11**	Endrin	µg/L	**<2.0**
Lindane (Gamma BHC)	µg/L	**<0.02**	Lindane (Gamma BHC)	µg/L	**<0.11**	Lindane (Gamma BHC)	mg/L	**<0.2**
Methoxychlor	µg/L	**<0.1**	Methoxychlor	µg/L	**<0.1**	Methoxychlor	µg/L	**<40.0**
Toxaphene	µg/L	**<1.0**	Toxaphene	µg/L	**<0.1**	Toxaphene	µg/L	**<3.0**
Dalapon	µg/L	**<1.0**	Dalapon	µg/L	**<0.2**	Dalapon	µg/L	**<1.0**
Di(2-ethylhexyl)adipate	µg/L	**<0.6**	Di(2-ethylhexyl)adipate	µg/L	**<0.5**	Di(2-ethylhexyl)adipate	µg/L	**<400.0**
Oxamyl (vydate)	µg/L	**<2.0**	Oxamyl (vydate)	µg/L	**<100.0**	Oxamyl (vydate)	µg/L	**<2.0**
Simazine	µg/L	**<0.07**	Simazine	µg/L	**<0.11**	Simazine	µg/L	**<4.0**
Picloram	µg/L	**<0.1**	Picloram	µg/L	**<100.0**	Picloram	µg/L	**<0.1**
Dinoseb	µg/L	**<0.2**	Dinoseb	µg/L	**<1.0**	Dinoseb	µg/L	**<0.2**
Hexachlorocyclopentadiene	µg/L	**<0.1**	Hexachlorocyclopentadiene	µg/L	**<0.1**	Hexachlorocyclopentadiene	µg/L	**<50.0**
Carbofuran	µg/L	**<0.9**	Carbofuran	µg/L	**<0.04**	Carbofuran	µg/L	**<40.0**
Atrazine	µg/L	**<0.1**	Atrazine	µg/L	**<0.1**	Atrazine	µg/L	**<3.0**

Alachlor	µg/L	**<0.2**	Alachlor	µg/L	**<0.1**	Alachlor	µg/L	**<2.0**
Heptachlor	µg/L	**<0.4**	Heptachlor	µg/L	**<0.1**	Heptachlor	µg/L	**<0.4**
Heptachlor epoxide	µg/L	**<0.02**	Heptachlor epoxide	µg/L	**<0.11**	Heptachlor epoxide	µg/L	**<0.2**
2,4-D	µg/L	**<0.1**	2,4-D	µg/L	**<10.0**	2,4-D	µg/L	**<0.1**
2,4,5-TP (Silvex)	µg/L	**<0.2**	2,4,5-TP (Silvex)	µg/L	**<4.0**	2,4,5-TP (Silvex)	µg/L	**<0.2**
Hexachlorobenzene	µg/L	**<0.1**	Hexachlorobenzene	µg/L	**<0.1**	Hexachlorobenzene	µg/L	**<1.0**
Di(2-ethylhexyl)phthalate	µg/L	**<0.6**	Di(2-ethylhexyl)phthalate	µg/L	**<0.5**	Di(2-ethylhexyl)phthalate	µg/L	**<6.0**
Benzo(a)pyrene (PAHs)	µg/L	**<0.02**	Benzo(a)pyrene (PAHs)	µg/L	**<0.11**	Benzo(a)pyrene (PAHs)	µg/L	**<0.2**
Pentachlorophenol	µg/L	**<0.04**	Pentachlorophenol	µg/L	**<1.0**	Pentachlorophenol	µg/L	**<0.04**
PCBs	µg/L	**<0.51**	PCBs	µg/L	**<0.1**	PCBs	µg/L	**<0.5**
Dibromochloropropane (DBCP)	µg/L	**<0.01**	Dibromochloropropane (DBCP)	µg/L	**0.5**	Dibromochloropropane (DBCP)	µg/L	**0.5**
Ethylene dibromide (EDB)	µg/L	**<0.01**	Ethylene dibromide (EDB)	µg/L	**0.5**	Ethylene dibromide (EDB)	µg/L	**0.5**
Chlordane	µg/L	**<0.2**	Chlordane	µg/L	**<0.1**	Chlordane	µg/L	**<2.0**
Volatile Organic Chemicals (VOC)			***Volatile Organic Chemicals (VOC)***			***Volatile Organic Chemicals (VOC)***		
1,2,4-Trichlorobenzene	µg/L	**<0.5**	1,2,4-Trichlorobenzene	µg/L	**0.5**	1,2,4-Trichlorobenzene	µg/L	**0.5**
CIS-1,2-Dichloroethylene	µg/L	**<0.5**	CIS-1,2-Dichloroethylene	µg/L	**0.5**	CIS-1,2-Dichloroethylene	µg/L	**0.5**
Xylenes (total)	µg/L	**<0.5**	Xylenes (total)	µg/L	**1.5**	Xylenes (total)	µg/L	**1.5**
Dichloromethane	µg/L	**<0.5**	Dichloromethane	µg/L	**0.5**	Dichloromethane	µg/L	**0.5**
o-Dichlorobenzene	µg/L	**<0.5**	o-Dichlorobenzene	µg/L	**0.5**	o-Dichlorobenzene	µg/L	**0.5**
p-Dichlorobenzene	µg/L	**<0.5**	p-Dichlorobenzene	µg/L	**0.5**	p-Dichlorobenzene	µg/L	**0.5**
Vinyl chloride	µg/L	**<0.5**	Vinyl chloride	µg/L	**0.5**	Vinyl chloride	µg/L	**0.5**
1,1-Dichloroethylene	µg/L	**<0.5**	1,1-Dichloroethylene	µg/L	**0.5**	1,1-Dichloroethylene	µg/L	**0.5**
trans-1,2-Dichloroethylene	µg/L	**<0.5**	trans-1,2-Dichloroethylene	µg/L	**0.5**	trans-1,2-Dichloroethylene	µg/L	**0.5**
1,2-Dichloroethane	µg/L	**<0.5**	1,2-Dichloroethane	µg/L	**0.5**	1,2-Dichloroethane	µg/L	**0.5**
1,1,1-Trichloroethane	µg/L	**<0.5**	1,1,1-Trichloroethane	µg/L	**0.5**	1,1,1-Trichloroethane	µg/L	**0.5**
Carbon tetrachloride	µg/L	**<0.5**	Carbon tetrachloride	µg/L	**0.5**	Carbon tetrachloride	µg/L	**0.5**

1,2-Dichloropropane	µg/L	**<0.5**	1,2-Dichloropropane	µg/L	**0.5**	1,2-Dichloropropane	µg/L	**0.5**
Trichloroethylene	µg/L	**<0.5**	Trichloroethylene	µg/L	**0.5**	Trichloroethylene	µg/L	**0.5**
1,1,2-Trichloroethane	µg/L	**<0.5**	1,1,2-Trichloroethane	µg/L	**0.5**	1,1,2-Trichloroethane	µg/L	**0.5**
Tetrachloroethylene	µg/L	**<0.5**	Tetrachloroethylene	µg/L	**0.5**	Tetrachloroethylene	µg/L	**0.5**
Chlorobenzene	µg/L	**<0.5**	Chlorobenzene	µg/L	**0.5**	Chlorobenzene	µg/L	**0.5**
Benzene	µg/L	**<0.5**	Benzene	µg/L	**0.5**	Benzene	µg/L	**0.5**
Toluene	µg/L	**<0.5**	Toluene	µg/L	**0.5**	Toluene	µg/L	**0.5**
Ethylbenzine	µg/L	**<0.5**	Ethylbenzine	µg/L	**0.5**	Ethylbenzine	µg/L	**0.5**
Styrene	µg/L	**<0.5**	Styrene	µg/L	**0.5**	Styrene	µg/L	**0.5**
Radionuclides			***Radionuclides***			***Radionuclides***		
Gross Alpha Particle Activity	pCi/L	**<2.0**	Gross Alpha Particle Activity	pCi/L	**6.5**	Gross Alpha Particle Activity	pCi/L	**1.9**
Uranium	pCi/L	**<2.0**	Uranium	pCi/L	**4.9**	Uranium	pCi/L	**0.00**
Radium 226 +228 (combined)	pCi/L	**<1.4**	Radium 226 +228 (combined)	pCi/L	**0.8**	Radium 226 +228 (combined)	pCi/L	**1.7**
Radium 228	pCi/L	**<1.0**	Radium 228	pCi/L	**0.0**	Radium 228	pCi/L	**0.6**
Gross Beta Particle Activity	pCi/L	**<4.0**	Gross Beta Particle Activity	pCi/L	**3.5**	Gross Beta Particle Activity	pCi/L	**3.5**
Microbiological			***Microbiological***			***Microbiological***		
Total coliform	CFU/100mL	**0**	Total coliform	CFU/100mL	**0**	Total coliform	CFU/100mL	**0**
E. coli	CFU/100mL	**0**	E. coli	CFU/100mL	**0**	E. coli	CFU/100mL	**0**
TTHM/HAA5 - Stage 1			***TTHM/HAA5 - Stage 1***			***TTHM/HAA5 - Stage 1***		
Total Trihalomethanes (TTHM)	µg/L	**27.8**	Total Trihalomethanes (TTHM)	µg/L	**2.00**	Total Trihalomethanes (TTHM)	µg/L	**2.00**
Total Haloacetc Acids (HAA5)	µg/L	**9.9**	Total Haloacetc Acids (HAA5)	µg/L	**<1.00**	Total Haloacetc Acids (HAA5)	µg/L	**<1.00**